W9132T-04-R-0014

Montana State University-Billings

Final Report - Addendum

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineers
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY03

Billings Armed Forces Reserve Center, Montana

October 18, 2006

Executive Summary

The Center for Applied Economic Research at Montana State University-Billings has completed operation, maintenance and repair of one (1) fuel cell system for the Montana Army National Guard. The unit completed one full year of operation on 4 December, 2005. The unit failed on 13 June 2006 and from that point was unrecoverable. Decommissioning took place on 23 August, 2006. The fuel cell manufacturer is Plug Power of Latham, New York. Project subcontractors include the following organizations: Montana-Dakota Utilities (gas supply, unit installation, commissioning, decommissioning and maintenance), Ace Electric (wiring, interconnection and decommissioning) and Wagner Mechanical (plumbing/CHP, water management and decommissioning). The Plug Power unit we were operating is a GenSys™ 5CS, rated at a maximum output of 5kW. The current operating set point is 2.5kW.

The unit was configured to serve a portion of the base electrical load at the Billings Armed Forces Reserve Center, located in Billings, Montana. It was fueled by natural gas and operated in parallel with the existing grid-supplied power. The project was configured for heat recovery.

The host site point of contact is Captain Gregory O. Olson. Captain Olson may be reached at: Gregory.o.olson@mt.ngb.army.mil

The benefits of this project were multiple. Two primary benefits were gauging unit performance under what may be considered as extreme environmental conditions and the second is educational. Well thought-out and extensive mechanisms were in use to maintain the flow of DI water into, through and out of the unit. Water management during extended periods of subzero temperatures provided a challenge to the team early on in the demonstration period. Secondly, we were able to assemble an extraordinarily strong team of partners, led by Montana-Dakota Utilities. It's the team that has made this project so successful, not one person or organization.

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1.0 Descriptive Title

Proton Exchange Membrane Fuel Cell Demonstration at the Billings Armed Forces Reserve Center, Montana Army National Guard, Billings, Montana (Mountain Geographic Region).

2.0 Name, Address and Related Company Information

Montana State University-Billings
Center for Applied Economic Research
1500 University Drive
Billings, MT 59101
(406) 657-1763

Data Universal Numbering System (DUNS) Number: 079713608
Taxpayer Identification Number (TIN): 816001642

Montana State University-Billings (MSU-B) is a comprehensive, regional, public university serving the educational needs of Montanans and is accessible to all who are qualified. MSU-B is an affiliate of the Montana State University family of campuses and has a student body of approximately 4,800. MSU-B is located in the largest city in Montana, Billings, which has a regional population of 123,000.
The Center for Applied Economic Research is a research and service organization for MSU-B. Its mission is to provide research and analysis to support economic development in the Yellowstone region that includes central and eastern Montana and northern Wyoming. The Center provides research services in energy markets and technology through grants, industry partnership agreements, collaborative studies, and customized contracts. Our website is www.msubillings.edu/caer

3.0 Production Capability of the Manufacturer

Plug Power, Inc.

Plug Power designs, develops and manufactures on-site electric power generation systems utilizing Proton Exchange Membrane (PEM) fuel cells for stationary applications. Plug Power's fuel cell systems are expected to be sold globally through a joint venture with General Electric and through DTE Energy Technologies in a four-state territory, which includes Michigan, Illinois, Ohio and Indiana. The Company's headquarters are located in Latham, N.Y., with offices in Washington, D.C., and The Netherlands. Plug Power's role in the Program will be to serve as fuel cell manufacturer and provide technical and operational support to Montana State University and its service provider.

Plug Power's manufacturing facility in Latham, New York opened in February 2000 and is comprised of 50,000 square feet of dedicated production and production test facilities. Plug Power employs approximately 100 personnel in its production areas. The production processes are designed around the principles of Lean Manufacturing, and use the Toyota Production System as a model. As such, planning and production is via a "pull system" that is, systems are produced only as orders pull demand for product through the production system. Lead-time for delivery is twelve weeks for large orders;
smaller orders can be fulfilled immediately.

Plug Power Inc. is a designer, developer, and manufacturer of on-site, energy generation systems utilizing proton exchange membrane fuel cells for stationary applications. The Latham, N.Y.-based company was founded in 1997 as a joint venture of DTE Energy Company and Mechanical Technology Incorporated. Plug Power Holland was established in February 2000 as the first European presence of Plug Power. Plug Power's fuel cell systems for residential and small stationary commercial applications are expected to be sold globally through a joint venture with the General Electric Company, one of the world's leading suppliers of power generation technology and energy services. DTE Energy Technologies will distribute these units in Michigan, Illinois, Ohio and Indiana. Systems will be distributed in Europe through Vaillant.

Our primary contact at PlugPower is:

Mr. Vincent Cassala
518-782-7700 x1939
vincent_cassala@plugpower.com

The items and services to be provided by PlugPower include the following:

Quantity	Description
1	GenSys 5CS fuel cell system with Standby Capability ("Product")
1	Service Agreement for Parts and Support
1	Shipment of GenSys 5CS and associated installation materials via flat-bed truck

4.0 Principal Investigator(s)

Mr. Brian Gurney
Energy Program Manager
Montana State University-Billings, Center for Applied Economic Research
Phone:(406) 657-2906 Fax: (406) 657-2327
Email: bgurney@msubillings.edu

5.0 Authorized Negotiator(s)

Dr. David McGinnis
Director of Grants and Sponsored Programs
Montana State University-Billings
Phone: (406) 657-2340
Email: dmcginnis@msubillings.edu

6.0 Past Relevant Performance Information

The Center is currently engaged in, or has completed, three distributed generation projects that involve fuel cells. The project portfolio includes the following:

1. Solid Oxide Fuel Cell Demonstration Project
Sponsor: Montana-Dakota Utilities
Dollar Value: $400,000
Point of Contact: John Delvo, (406) 896-4241
Description: A partnership with Montana-Dakota Utilities, Global ThermoElectric and the Center for Applied Economic Research will result in the acquisition, installation, operation, maintenance, monitoring and removal of 2 SOFC's. The first unit will be a residential application while the second unit will be placed in a rural/remote setting.

2. Reducing Barriers to Distributed Generation
Sponsor: Montana Department of Environmental Quality through a grant with the US Department of Energy
Dollar Value: $100,000
Point of Contact: Mark Hines, (406) 444-6769
Description: The goal of this project is to identify a set of regulatory and business process best practices for the marketing, installation and servicing of small-scale distributed generation devices. One of the tasks in this project is to identify peculiarities with fuel cells, such as policies that encourage market adoption of fuel cell products through energy efficiency programs rather than renewable energy incentives. Simulations will be run to evaluate alternative business processes and identify best practices that minimize transaction costs associated with marketing, installing and servicing distributed generation units in residential and commercial settings.

3. Big Sky EDA Fuel Cell Project
Sponsor: Big Sky Economic Development Authority
Dollar Value: $54,000
Point of Contact: Dan Stevenson, CTA, Inc. (406) 896-6171
Description: Conducted analyses of the market for fuel cells, including a survey of households.

7.0 Host Facility Information

Military Facility Site 1:	Montana Army National Guard Billings Armed Forces Reserve Center 2915 Gabel Road Billings, Montana 59102
The Host Site POC Contact is:	Captain Gregory Olson Billings Armed Forces Reserve Center Phone: (406) 655-6220 Fax: (406) 655-6229 Email: gregory.o.olson@mt.ngb.army.mil
The State Facilities Management POC is:	Mr. Clay White, Energy Manager Montana Dept. of Military Affairs Construction and Facilities Management Office Phone: 406-324-3125 Email: Clay.white@mt.ngb.army.mil
Facility Electricity Provider:	NorthWestern Energy
Fuel Provider:	Montana-Dakota Utilities

Billings Armed Forces Reserve Center

- Designed in 1997-98
- Constructed in 1999
- 113,300 +/- square feet
- Facility is called the Billings Armed Forces Reserve Center
- Houses a US Marine Reserve Unit and 3 units from the Montana Army National Guard
- Facility includes spaces such as:
    - Mess Hall
    - Assembly Hall
    - Indoor Firing Range
    - Classrooms
    - Administrative spaces
    - Parachute drying tower
    - Military equipment supply rooms and weapons vaults

- Etc.

- 45,000 sq. ft. addition completed 1st quarter 2006

Figure 1 - Billings Armed Forces Reserve Center

8.0 Fuel Cell Installation

On 11 June, 2004, our team hosted the project Kickoff Meeting. This was the first time that the Montana Department of Military Affairs (DMA) had been given the opportunity to view the complete set of plans that were generated by the project engineering firm of record, Associated Construction Engineers (ACE) of Billings, MT. ACE had worked with the DMF before, and we wanted to contract with ACE to stay within this comfort zone for the DMA. Two representatives from the DMA, John Horn-Contracts Specialist and Scott Cromwell-Architect, joined us at the meeting.

On 14 June, DMA notified the team that there were 16 items that required further review/information/analysis/clarification. The "Design Review Record" issued by the DMA is located in **Appendix A**. Twelve of the sixteen items were able to be addressed by ACE, however the other four required the services of a structural engineer. To maintain the thread of continuity with DMA, we went to A&E Architects of Billings, who was a partner when the facility was originally constructed. Because of the workload at A&E, the project was delayed approximately 11 weeks. On 6 September, A&E issued a letter (**Appendix B**) to the team and DMA that satisfied DMA to the point where they were willing to go forward and issue a contract to the team to proceed with installation. The overarching concern for the DMA was that we did not hit or cut the thick reinforcing cables that are threaded inside the pre-stressed panels that comprise the exterior of the structure. As it turns out, the cables are 18 inches above the base of the panel and that is above where the holes were bored into the panel. The DMA/MSU-B contract can be found in **Appendix C**

The Montana Department of Military Affairs is a great group to work with. Scott Cromwell, AIA, has been very helpful in providing access to the building and data contained in this report. Even though some time was lost, many of their ideas and suggestions are threaded throughout the project.

Additionally, the project would not be possible without the participation and support of Montana-Dakota Utilities. John Delvo, P.E., and many others were instrumental in the installation process and do a great job at operation/maintenance/repair of the unit.

The Installation Process

- **1 October to 10 November – Pour pad**

Figure 2 - 10" pad with 4" drain

- **Bore Holes Into Host Site –**

Figure 3 - 3" and 10" holes for infrastructure

- **Set Unit**

Figure 4 - Set unit and center over drain

- **Run External Connections**

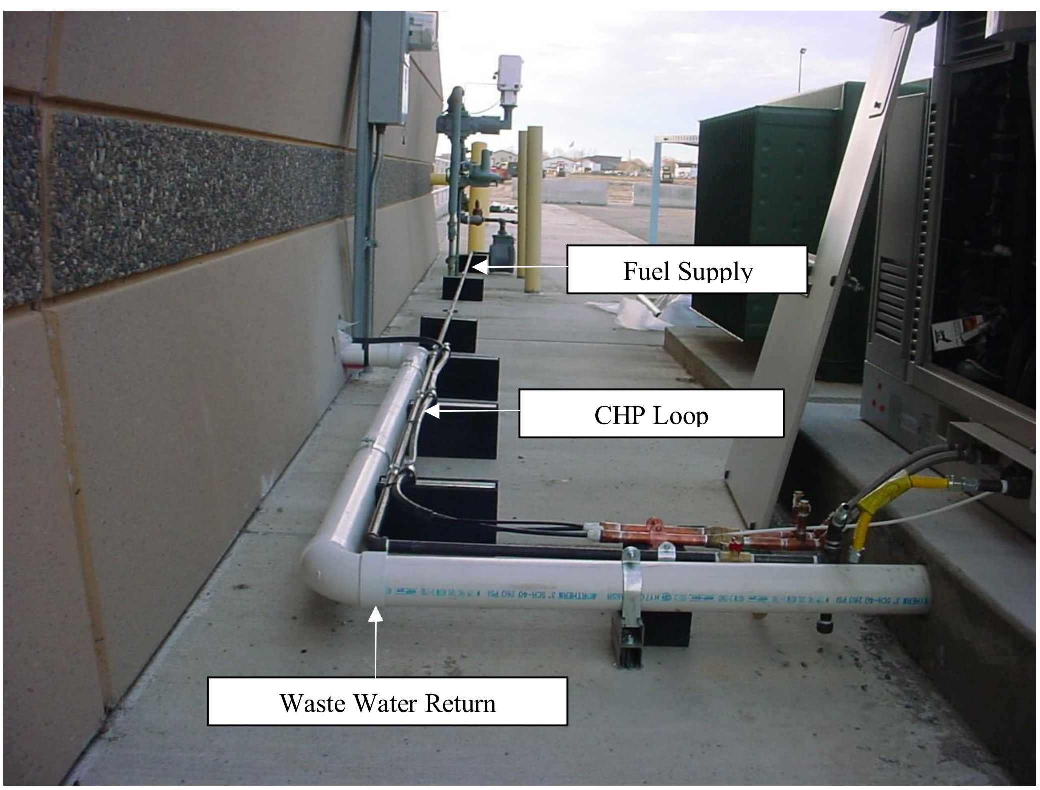


Figure 5 - NG and Water supply, waste water return and CHP loop

- **Install Heat Exchanger for CHP**

Figure 6 - Heat Exchanger Model G4408LD, http://www.taco-hvac.com/

- **Interior Infrastructure, Partial**

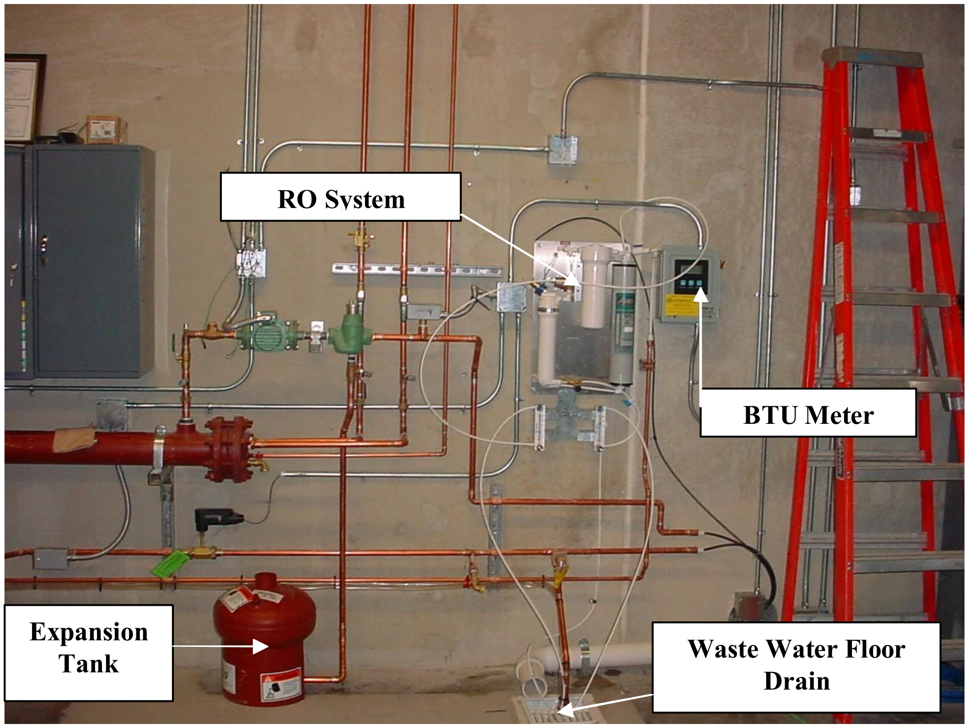


Figure 7 - BTU Meter, ONICON System 10, http://www.onicon.com/

- **Partial CHP Loop**

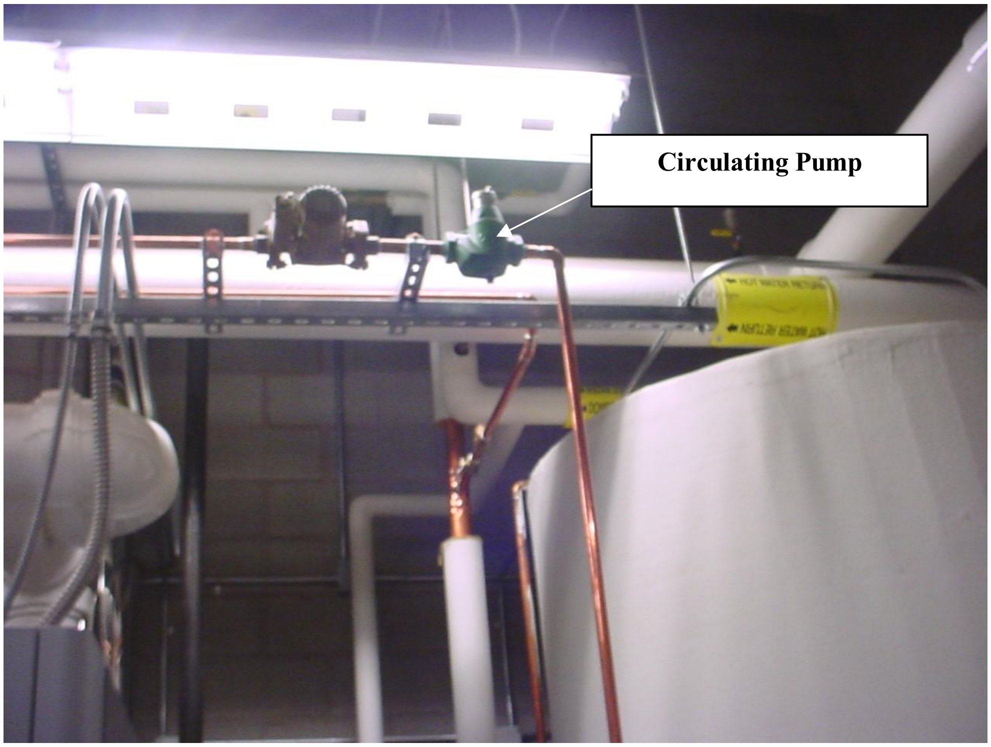


Figure 8 - Partial CHP loop to boiler, recirculating pump Model 009, http://www.taco-hvac.com/

- **Exterior electrical output infrastructure**

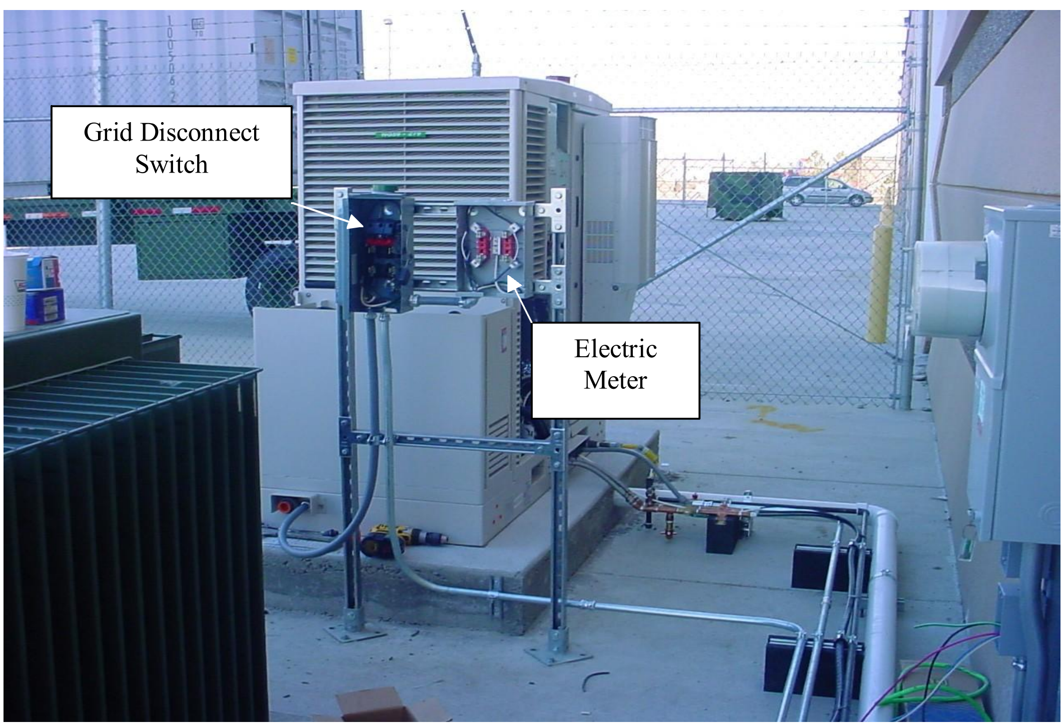


Figure 9 - Grid disconnect switch and electric meter

- **Unit Prep**

Figure 10 - Install fuel cell stack

Figure 11 - Thermonal added to unit

Unit Startup

Startup was initiated on 11 November, 2004 at 8:00 am. Two, Plug-trained MDU technicians were on site as was a Plug-trained PE for MDU. Success to startup was approximately 20 hours in duration and was completed at 6:00 am on 12 November. The team dealt with the following sequence of events during this time:

Problem 1

- Warning 404, Timeout Hum Fill Alert
- **Failure-** Polishing hose leaking on entry side
- **Fix-** Reinsert hose into filter/fitting
- **Possible Cause-** Jarred loose during shipping?

Problems 2-5

- Shutdown Code 333, Process Exhaust Temperature High
- **Fix-** Restart

Lesson Learned- Discovered that DI tank automatically empties itself when the temperature sensor senses a temperature of something less than 40 degrees. Since the ambient temperature was dropping into the 20's during this process, we found ourselves literally starting over to fill the DI tank and the humidifier to bring the unit to the "running" state. Each iteration cost us approximately 4 hours.

Note: Since the temperature was going to drop into the low 20's on this night, about 2 am MDU went and purchased 2 1500 watt electric heaters and two 12' X 14' tarps. We tented-in the fuel cell for about 5 hours to get it through the coldest part of the night. Our fear was that water had already been circulating through the various hoses, pumps, sensors, etc., and we did not want ice to form because we were not in a "full run" mode.

We did not experience any difficulty with the local permitting process. It was helpful that the various city departments (Building, Fire, Water, etc.) were contacted earlier in the year and had a chance to ask questions and review unit spec data that was provided by Plug. The cost of the permitting process was $1,396.

Man-hours needed to complete the installation-

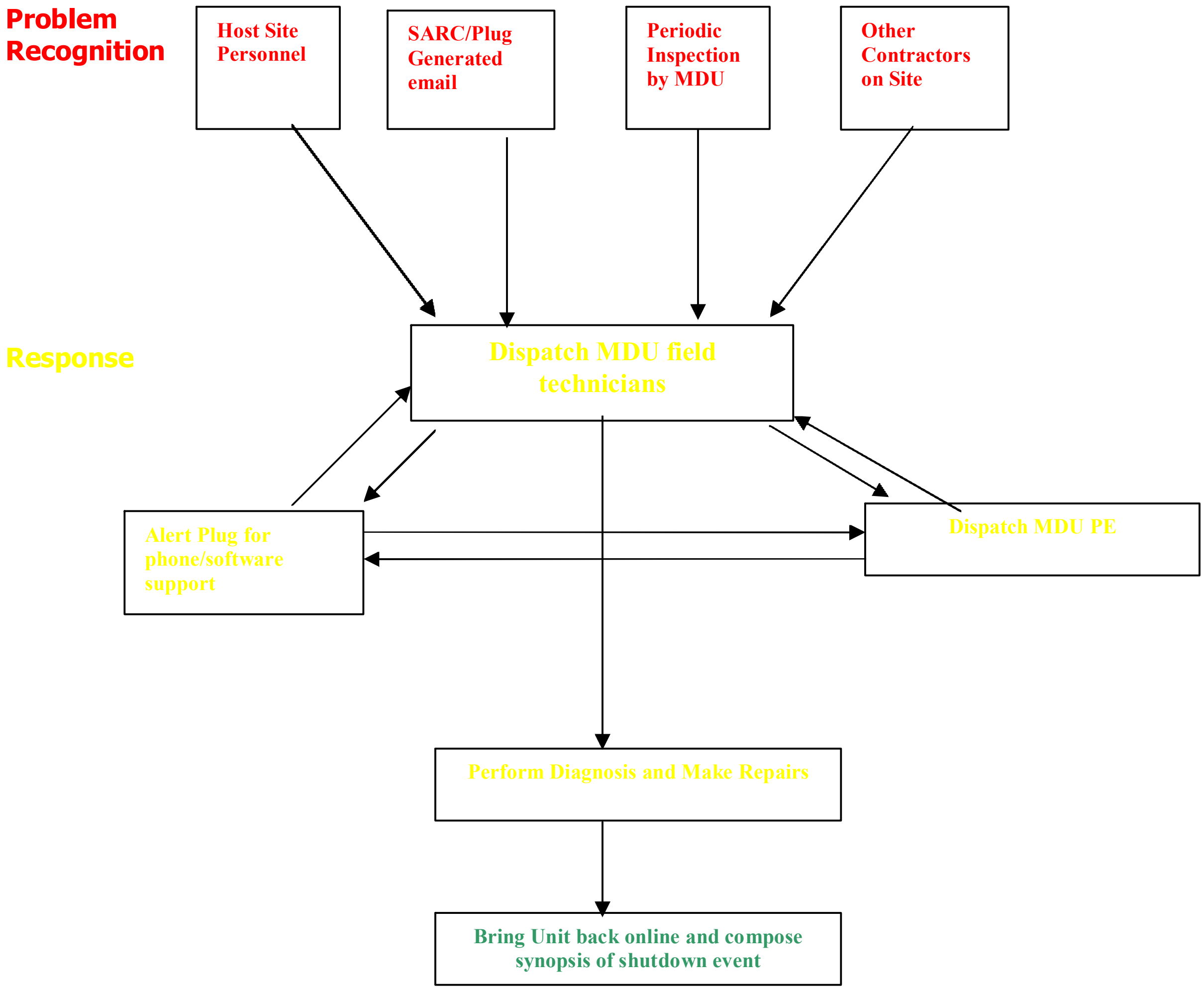
Company	Man-hours
Montana-Dakota Utilities	59.5
Ace Electric	130
Wagner Mechanical	120
Total	**309.5**

The fuel cell is feeding an electrical panel in the mechanical room which serves the boilers, pumps, condensers and other mechanical equipment. Hot water is being recovered and contributing to the heating needs of boiler system.

NorthWestern Energy, the host site electricity provider, chose not to pursue a formal interconnection agreement. Their largest concern was that the unit "have an electric disconnect installed to prevent "islanding" the system (feeding electricity into the grid when the NorthWestern system is down). The unit has the ability to terminate its electrical output when the grid is down, and this has already been tested at the site. Additionally, there is a manual breaker which is labeled and located next to the unit. The OK to go forward with the installation can be found in **Appendix D.**

The fuel cell power set point is 2.5 kW and the current fuel consumption is approximately 960 cu.ft./24 hours. Additional monitoring equipment that is directly tied to the unit includes an electric meter, a gas meter and a BTU meter.

The operating procedures were laid out as follows:



* MDU has trained 2-3 people in the military who work at the site on a frequent basis to investigate and perhaps record some of the data generated by the instruments and gauges as they walk through the area on their daily routine.

9.0 Electrical System

The fuel cell electrical system is dual function, capable of grid parallel and/or standby operation. This fuel cell installation is operating in the grid parallel configuration. This is the standard operating mode of the fuel cell. The system generates power at a fixed set point of 2.5 kW and sends it to the facility. Unused power is sent to the grid or, if more power is needed, it will be taken from the grid. This is done by back-feeding a 50-amp breaker in an existing electrical panel. In this type of interconnection, if the grid fails, the system will safely isolate itself from the grid. Upon return of the grid, the system will synchronize itself and reconnect with the grid.

Fuel cell output is 120 VAC @ 60 Hz, single phase line to neutral with a separate ground. The system is considered a utility interactive current source which automatically synchronizes itself to the grid's voltage and frequency.

The typical monthly load of the host site in support by the grid is 47,753 kWh/mo.

The fuel cell is rated for 5 kW (5 kVA) maximum, and 10 kVA for 5 seconds of overload conditions. The minimum set point is 2.5 kW (2.5 kVA). However, the system will follow any 0 to 5 kW load at the critical load panel in standby mode. The system has a unity power factor, pf = 1.0.

An automatic transfer switch is internal to the inverter which is designed to automatically isolate itself if over/under voltage is detected. Islanding protection is certified by Underwriters Laboratories to the UL 1741 standard.

The inverter has a microprocessor based controller that senses the grid, feeds the signal back and outputs the matching synchronized signal.

System controls are internal to the system and are designed and manufactured by Plug Power. These controls are microprocessor based. This fully integrated system is self controlling.

The electrical portion of the installation process came along rather well. We would have preferred that the installation of the electrical infrastructure be completed 24 hours earlier than when it was completed on 11 November, however, in defense of the electrical contractor, they did stay into the evening to ensure that there were no electrical glitches on the road to startup. It should also be noted that the MDU PE on site during the installation process was able to suggest to the journeyman electrician what the ideal location was for meters, manual disconnect switch, etc.

The electrical scope of the installation included:

- 120v incoming line voltage
- 120v outgoing load voltage fed into the electrical panel which serves the boiler room mechanical loads
- 24v control wiring for pump controls
- 120v power wiring to the circulation pumps
- 48vdc data line for monitoring by Plug Power
- 120v electric heat tracing on the exposed water lines
- 120v electric hour-watt meter to monitor power output
- Various conduit, copper wiring and steel fittings

10.0 Thermal Recovery System

1. Provide a complete description of the fuel cell thermal recovery system

What is the CHP heat recovery loop and can the system be operated without one installed?

The CHP heat recovery loop is a customer-supplied system that circulates a heat transfer fluid (typically propylene-glycol/water mixture) from the fuel cell to the customer-supplied system using the heat (existing domestic hot water tank). The fuel cell system is designed to operate normally if there is no CHP loop installed or if the customer demand at any time is zero. The excess heat generated by the fuel cell will simply be discharged through the existing radiator.

The system should be designed to meet the following specifications:

Flow: 0-10 gpm (1-2 gpm will maximize heat reclamation from the fuel cell – **we are balanced at 1 gpm)**

Pressure: <= 30 psig

Temperature: (installation specific) with a flow rate of 1-2 gpm, the return temperature to the customer-supplied system will be approximately 140^{o}F

Available heat:

- 11,200 BTU/hr @ 2.5kWe

2. Define the fuel cell thermal output, and the thermal loads supported by the fuel cell.
Temperature: (installation specific) with a flow rate of 1-2 gpm, the return temperature to the customer-supplied system will be approximately 140^{o}F – **we are at 133 degrees F.**
Available heat:

- 11,200 BTU/hr @ 2.5kWe

3. State the operating modes of the thermal recovery system, continuous, intermittent, seasonal, etc.
Intermittent/Continuous: Depends on the demand for heat from the domestic hot water tank – excess heat will be rejected through fuel cell radiator.

The fuel cell system is designed to operate normally if there is no CHP loop installed or if the customer demand at any time is zero. The excess heat generated by the fuel cell will simply be discharged through the existing radiator.

4. Describe the interconnection process of the fuel cell thermal recovery system to the facility.
The CHP heat recovery loop is a customer-supplied system that circulates a heat transfer fluid (typically propylene-glycol/water mixture) from the fuel cell to the customer-supplied system using the heat (existing domestic hot water tank).

Piping connections will be made from the domestic cold water line to the installed heat exchanger tube bundle. This cold water will be heated by a closed-loop propylene-glycol/water mixture which circulates from the fuel-cell through the heat exchanger tube bundle and returning back to the fuel-cell. The result is domestic hot water which will tie back into the existing storage tank adding more hot water to the system.

5. The engineering drawings are included as a separate file for this report.

11.0 Data Acquisition System

All operational data is sent automatically by the system (once per day) via modem/dial up connection to Plug Power where it is entered into the fleet database. Also, during every system shutdown, the unit automatically reports to Plug Power it's status, transmits data and a service call is then made.

Complete system operational data can be obtained directly from Plug Power or downloaded by a trained service technician with a laptop and RS232 connection cable. This data can be used for reporting and/or troubleshooting. Typical data used for reporting (non-sensitive) are run hours, power output, gas consumption, efficiency and availability.

The Billings, MT office of the National Weather Service is supporting the project by providing the hourly observation data in proximity to the host site. During the demonstration period, a series of HTML files were transmitted and included captured data on an hourly basis of numerous environmental parameters for the month. Note that some observations may be more frequent than by the hour if environmental conditions are in the midst of change.

MDU did install a standard gas meter upstream of the fuel cell, an electric meter downstream for the fuel cell and a Btu meter. These three devices will be read once a week and compared with the operational data that Plug is obtaining.

Fuel Cell Performance as of 13 June 2006 (provided by Plug Power)

Run Time (hours)	12898.19
Time in Period (hours)	13440
Availability (%)	96%
Energy Produced (kWe-hrs AC)	32234.55
Output Setting (kW)	2.5
Average Output (kW)	2.50
Fuel Usage HHV (BTU's)	4.27E+08
Fuel Usage (SCF)	422785.7221
Electrical Efficiency (%)	25.76%
Thermal Heat Recovery (BTU's)	68398100
Heat Recovery Rate (BTU's /hr.)	5302.922
Thermal Efficiency (%)	16.01%
Overall Efficiency (%)	41.77%
Number of Scheduled Outages	6
Scheduled Outage Hours	77.7
Number of Unscheduled Outages	9
Unscheduled Outage Hours	454.31

12.0 Fuel Supply System

The GenSys 5 kW fuel cell system at the Billings Armed Forces Center is fuel by natural gas. The piping for gas supply is ½ "schedule 40 black pipe. The gas pressure supplying the unit is at 4 OZ. or approximately 7"of water column. There where no challenges, changes or deviations from the proposed plan. This unit installed no different than installing a natural gas furnace for a home.

13.0 Program Costs

FINAL REPORT OF EXPENDITURES

	BUDGET	PRIOR CUMULATIVE	CURRENT EXPENDITURES	CUMULATIVE EXPENDITURES	BUDGET BALANCE
FUEL CELL COSTS					
PLUG POWER	55,000.00	55,000.00		55,000.00	0.00
SERVICE AGREEMENT	15,000.00	15,000.00		15,000.00	0.00
TRAINING	9,600.00	6,620.86		6,620.86	2,979.14
INSTALLATION					
WAGNER	5,280.00	5,280.00		5,280.00	0.00
ACE ELECTRIC	4,160.00	8,320.00		8,320.00	(4,160.00)
ENGINEER	7,000.00	7,000.00		7,000.00	0.00
SERVICES & EQUIPMENT					
CRANE	500.00	500.00		500.00	0.00
NATURAL GAS SERVICE	2,998.00	2,997.78		2,997.78	0.22
THERMAL RECOVERY COSTS					
WAGNER	4,422.00	4,422.00		4,422.00	0.00
EQUIPMENT					
BTU METER	3,000.00	2,488.01		2,488.01	511.99
PERFORMANCE MONITORING					
PRINCIPAL INVESTIGATOR	6,525.96	3,575.85	10,804.85	14,380.70	(7,854.74)
PHONE LINE (MODEM)	470.00	0.00		0.00	470.00

MAINTENANCE COSTS					
TECHNICIAN MDU	6,240.00	7,405.00		7,405.00	(1,165.00)
PROJECT MANANGEMENT					
PRINCIPAL INVESTIGATOR	20,793.50	21,066.47		21,066.47	(272.97)
TRAVEL COSTS					
MANAGERIAL	3,895.40	373.11	24.00	397.11	3,498.29
TECHNICIAN	8,905.60	4,846.67		4,846.67	4,058.93
DECOMMISSIONING					
REMOVE ELECTRICAL	6,400.00	1,125.00	527.00	1,652.00	4,748.00
OTHER COSTS					
ELECTRICAL	9,248.00	9,248.00		9,248.00	0.00
PLAN REVIEW FEE	0.00	550.19		550.19	(550.19)
BUILDING PERMIT	0.00	846.45		846.45	(846.45)
GAS FUEL	1,765.00	0.00		0.00	1,765.00
DELIVERY CHARGE	500.00	3,650.00		3,650.00	(3,150.00)
COMPUTER TIME	236.16	0.00		0.00	236.16
WATER	130.00	0.00		0.00	130.00
WATER ANALYSIS	0.00	200.00		200.00	(200.00)
ARCHITECTUAL DESIGN FEE	0.00	1,000.00		1,000.00	(1,000.00)
COPY PLANS	0.00	100.00		100.00	(100.00)
OTHER (FOOD)	0.00	66.00		66.00	(66.00)
OTHER (POSTAGE)	0.00	14.00		14.00	(14.00)
OTHER (FED EX)	0.00	77.66		77.66	(77.66)
OTHER (GARY AMUNDSON)	0.00	583.73		583.73	(583.73)
OTHER (OFFICE SUPPLIES)	0.00	48.75		48.75	(48.75)
INDIRECT COSTS	13,765.57	0.00	12,073.81	12,073.81	1,691.76
TOTAL	185,835.19	162,405.53	23,429.66	185,835.19	(0.00)

* Please recall that the original budget forwarded to CERL was slightly less than 200K. In subsequent communications, CERL requested that the budget be reduced. Our group has provided monetary support when the project required it.

[1] We canvassed 2-3 trucking/freight forwarding companies about the cost to ship 2,000 lbs. from Latham, NY to Billings, MT. All of the quotes came in at $200-300. Hence, we placed $500 in the budget to cover freight and perhaps some additional insurance. Plug Power asked if we could take delivery in the first week of April 2004. We were surprised that Plug contracted with a private carrier whose entire load was comprised of 1 fuel cell. Therefore, we underestimated by $3,150.

[2] This fee is for the services of a structural engineer to address a request for information made by the Montana Department of Military Affairs.

14.0 Milestones/Improvements

November 2004-

The unit was commissioned on 16 November.

Due to climate, we found that the DI water lines began to ice-up. This was corrected when we encased all of the infrastructure lines with insulation and a plywood exterior was constructed as shown below.

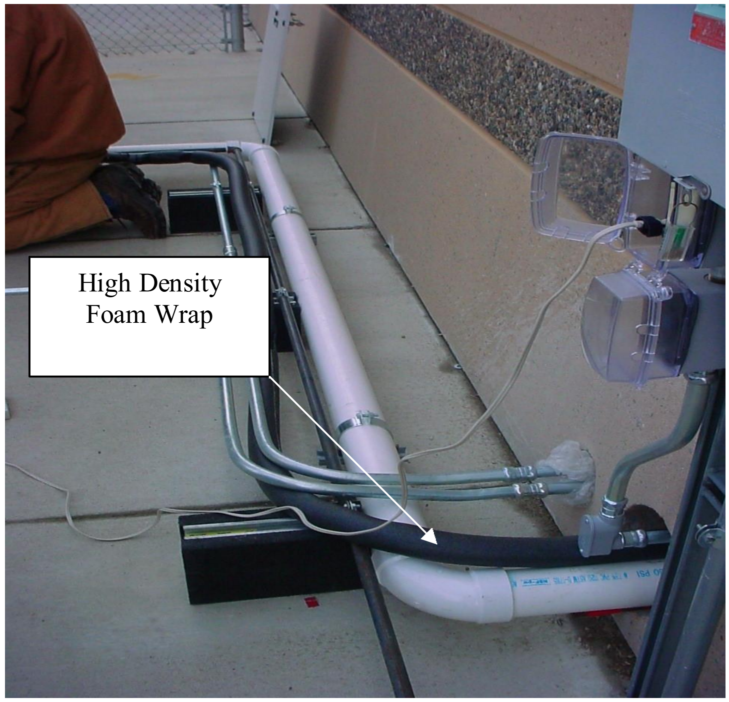


Figure 12 - Correction for DI line freeze-up

Figure 13 - Plywood encasement to prevent DI line freeze-up. Fiberglass insulation laid inside interior of encasement.

December 2004 –

An inline propylene glycol heater was installed and system software was upgraded to v. 1.31. We began to experience leaking problems in the RO system, particularly with the mixed bed filter.

January 2005 –

Two filters (mixed bed filters) began leaking during the month and were replaced. The unit was threatening to shut down due to lack of water, and simultaneously water would be accumulating on the floor beneath the mixed bed filter.

February 2005 –

MDU replaced the carbon filter and the mixed bed filter. MDU installed a water pressure gauge to monitor line pressure at various points in the RO system.

March 2005 –

We replaced two additional mixed bed filters during the month and returned 3 mixed bed filters to Plug Power for inspection. However, by the end of the month, we had isolated a water pressure anomaly in the RO system that was 2X Plug's specifications.
The software was upgraded to v. 1.32.

April 2005 –

The rotometers in the RO system were reconfigured to meet spec for the pressure (15 psi) to enter the mixed bed filter. This solved the problem of "blowing" mixed bed filters that we had experienced over the past 100+ days.
A software upgrade to the SARC was performed on 8 April. The "data logging set points" were not reset, and this caused no data to be transferred to Plug Power from 8 April to 28 April. Hence our contract demonstration period was extended to 4 December 2005 in order to maintain the continuity of 1 full year of operating data.

May 2005 –

The unit attained 100% availability.

June 2005 –

The unit maintained 100% availability.

July 2005 –

This was a misleading month in regard to availability. A power outage in Latham, NY at Plug Power would not allow our unit to 'call in' and transmit data. After several attempts to call in, our SARC board locked-up and ultimately was required to be reset, which was performed by MDU. *But its important to understand that the unit did not go down due to problems it created or that were created by the host site.*

August 2005 –

The unit experienced the failure of a power distribution board (PDB). *Again I must caution the reader, we experienced a local outage that lasted some 90 minutes and there is some possibility that a surge or spike caused this failure. It wasn't a stack, inverter, reformer, etc. issue, it was an environmental event.*

September 2005 –

The unit attained 100% availability.

October 2005 –

The downtime associated with this month came about due to a clogged air inlet filter for the fuel cell stack. It was a preventive maintenance item that we should have addressed 6 months earlier, however we did not realize its presence or significance. A photograph of the air inlet/filter is shown below.

Figure 14 - Stack air inlet filter.

November 2005 –

The unit attained 1 full year operation on 15 November.
November was dedicated to a series of preventative maintenance chores. A list of tasks performed are presented below:

1) Installed new Enthalpy Wheel, no problems.
2) Installed new DI Polishing Filter had a few leaks during startup and replaced the leaky fitting with a new O ring.
3) Installed new FS3 air flow sensor, no problems.
4) Installed a new air filter on the electronics' enclosure no problems.
5) Replaced air filter on the inlet air-filter box that pre-filters the air for the fuel stack, no problems.
6) Replaced desulphurization canister; no problem.
7) Changed battery charging set point voltage to 54.5 V this was recommended from Plug Power.

December 2005 –

The unit attained 100% availability.
We formally requested CERL to extend our demonstration period.

January 2006 –

The unit functioned flawlessly during January with 100% availability.

We were granted an 8-month extension from CERL to continue operating the unit.

The National Weather Service agreed to continue to provide hourly observation data on a month-by-month basis.

Montana-Dakota Utilities agreed to continue to provide maintenance and repair of the unit.

As requested by CERL, the team submitted an Interim Final Report to Mr. Scott Kenner, PE, Concurrent Technologies Corp.

February 2006 –

The unit attained 100% availability for February.

March 2006 –

The unit attained 100% availability for the month of March and crossed the 11,000 hour Run Time threshold during the month.

April 2006 –

During the first week of April we performed some PM tasks. By the end of the second week we began to experience a series of outages. The ultimate cause was a failed propylene glycol pump. A replacement pump was installed on 28 April. The series of problems stemming from the failure of the pump cost the project 15 days of downtime. A photograph of the failed pump, including the broken impellor is shown below.

Figure 15- Propylene Glycol Pump

Figure 16 - Cracked Impellor on Propylene Glycol Pump

May 2006 –

The unit attained 100% availability for May. We crossed the 12,000 hours Run Time threshold in May.

June 2006 –

On 13 June the unit went down due to "low battery." Apparently, other work was being performed at the host site, and in doing so, the breaker to the fuel cell was manually turned "off," and wasn't returned to the "on" position until the following day.

On 14 June a Remote Start was attempted by Montana-Dakota Utilities and ultimately they were unsuccessful due to "low batteries."

On 15 June, the PI and MDU went to the host site and attempted the startup 2 times and were unsuccessful. We decided to attempt to charge the batteries by connecting 3 battery chargers, all on "boost." A photo of our attempt to restore the batteries is shown below.

Figure 17 - Attempt to restore battery power

On 16 June, the PI and MDU made the last attempt to restart the unit. We would get as far as "Stack Health II," but the battery voltage would continue to drop during startup, and ultimately when it reached 46 volts, the unit would shutdown. At this point, we declared the unit to be unrecoverable.

15.0 Decommissioning/Removal/Site Restoration

Decommissioning, Removal and Site Restoration were carried out on 23 August, 2006. The organizations that addressed these tasks and their associated costs are provided in the table below.

Organization	Cost	Hours
Wagner Mechanical	$900.00	14 man hours
Ace Electric	225.00	5 man hours
Montana-Dakota Utilities	302.00	4 man hours

On 15 August 2006, the Montana Department of Military Affairs responded affirmatively to a letter dated 11 August which outlined 8 specific tasks that would need to be carried out in order for site restoration to be approved. The agreed upon tasks and accompanying photos detail the Removal/Site Restoration steps that were completed.

- Cap the drain pipe on top and side of concrete pad – removing drain piping from the pad to the floor drain

Figure 188 - Capped Drain Piping on Top and Side

- Install metal caps with silicone seal on the exterior/interior of the building to cover the holes that were bored to support the unit. Fill holes with insulation prior to capping holes

Figure 19- Exterior Metal Cap

Figure 20 - Interior Metal Cap

- Disconnect and remove the telephone line

  Task Complete

- Cap the CHP system just below the unistrut pipe support and remove all infrastructure below the capped lines, including removal of the expansion tank, heat exchanger, reverse osmosis system, BTU meter, etc.

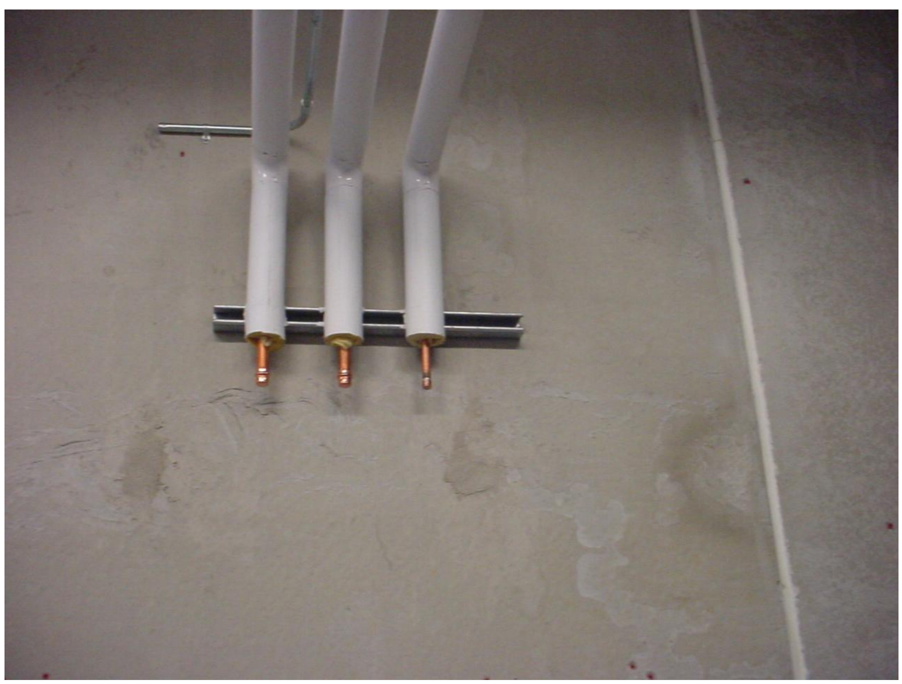


Figure 21 - Capped CHP system below unistrut pipe support

Figure 22 - Removed expansion tank, heat exchanger, natural gas meter, RO system & BTU meter

Figure 23 - Interior wall, post decommissioning

- Disconnect the 4-wire lead at the breaker box and remove wire and associated conduit

  Task Complete

- Remove natural gas meter and associated piping and plug the meter test tee – this will bring the gas piping back to its original state

  Task Complete. See Figure 22.

- Remove conduit leading to and from the fuel cell disconnect switch, but leave the electric meter and disconnect switch in place

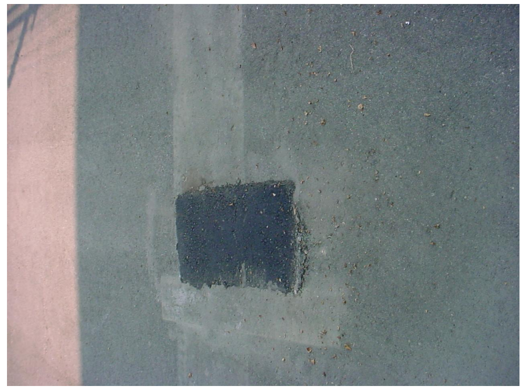
Figure 25 - Remove conduit to & from disconnect. Meter and disconnect left in place.

- Removal of fuel cell to site TBD

Figure 26 - Removal of fuel cell (the unit is currently in storage at a MDU facility)

The only problem we experienced during the decommissioning process was the removal of the Jersey Wall. During this step, a fork on the forklift accidentally gouged a hole in the asphalt pavement, in front of the housekeeping pad. We contracted with a local paving company to make repairs ASAP. This has been addressed, and "before" and "after" photos are shown below.

Before Repair



After Repair

Upon completion of all decommissioning tasks, we requested that the Montana Department of Military Affairs approve the site restoration and release the project. The communication between the Department of Military Affairs and the project team is located in **Appendix E.**

16.0 Additional Research/Analysis

It will be a considerable advantage when the external plumbing (ie. RO system) is no longer needed. Our understanding is that the 'next generation' unit from Plug Power will no longer require an external RO system.

MDU became 'pros' at responding to the mixed bed filter failure. They knew that they had 45 minutes from the text message to actual system shutdown to get the problem corrected, and did so on many occasions early on in the project. Kudo's to them!

It would probably help if Plug Power were to publish a laminated, 1-page document (perhaps both sides?) that contains a 'cheat sheet' style PM schedule. A sample format may be structured as follows:

Replace Polishing Filter	Every 6 months
Replace Fuel Cell Air Inlet Filter	Every 3 months
Inspect CHP fittings/couplings	Monthly

A good amount of our downtime can probably be 'engineered out.' For example, can the Power Distribution Board be engineered so that it is more tolerant/ better able to handle spikes and/or surges produced by grid power? Can the SARC board be engineered such that if it is unable to make a remote connection, it simply 'times itself out' for 24 hours but continues to collect and store the necessary data for Plug and their stakeholders?

Open questions for CERL from a research perspective:

When the propylene glycol pump failed, the stack went for over 2 weeks without being hydrated. And prior to that, we question whether sufficient fluid was being circulated until actual failure. In May, when we attained 100% availability, we noticed that a number of membranes had been weakened and they were all clustered at one end of the stack (at least our real time software when plugged into the unit showed blue bars that trailed off significantly on one end on the screen).
So the overall question is: "Did our stack experience a shortened life due to primarily dehydration issues? And, "Would it have been possible to generate additional electrical output from the unit (2 months, 3 months?) if the batteries had not failed?

17.0 Conclusions/Summary

As of 10/18/06, the project cost was $185,835.19.

It's important to acknowledge that the success of this project is beyond one person or one organization.

The local electric utility, the City of Billings, MT, and our Engineer of Record opened the doors to allow us to proceed.

Our electrical and mechanical contractors performed wonderfully. When William Taylor from CERL attended the commissioning, he commented that he hadn't reviewed too many sites where the installation was this clean.

Our site host, the Montana Army National Guard has been exceptional. Personnel at the facility call MDU if they detect anything out of the ordinary. Once appropriate security clearances were made, MDU was granted a key to the utility area to perform inside work/inspection. We appreciate their willingness to host this technology in Montana.

Plug Power has certainly pulled their load. Whether it's telephone support, FedEx'ing a critical component when the unit was down or providing monthly data for the PI, they have never failed us.

I purposely saved the best for last. Whenever there was a problem with the fuel cell, I have yet to arrive at the host site before Montana-Dakota Utilities. I can recall an incident whereby John Delvo, PE excused himself from a dinner engagement to respond to a text message that the fuel cell was going down. The unit was recovered before 1 minute of downtime occurred.
The MDU technicians that were trained at Plug Power have performed with the utmost professionalism. It's an honor to be affiliated with this organization. Thank you.

DMA-FMO

Design Review Record

Project: **BAFRC - Fuel Cell**	Design Phase: **Construction Documents**
Comments by: **Scott Cromwell, Chris Denning, John Horn and Brian Moloney**	Date: **June 14, 2004**

Comment Number	Detail/Sheet or Spec. Section	Review Comments	Comment Response (for A/E use)
1	6/MPE1	Provide sleeve and/or core drill detail to penetrate existng precast wall panel at all locations. Size of sleeve or hole, sealant, and compaction of soil and gravel must be addressed. Verify height and location above footing that penetrations will be made. Coordinate detail with original building structural	To Be Addressed By A&E Architects SEE A&E ASK-001 DETAIL
2	26/MPE1	Show extents of concrete/asphalt cutting and removal interior and exterior.	To Be Addressed By A&E Architects SEE A&E ASK-002
3	26/MPE1	Provide section detail of 12" housekeeping pad.	To Be Addressed By A&E Architects SEE A&E ASK-003
4	26/MPE1	Dept. of Military Affairs has suggested that the surface around the housekeeping pad and bollards remain open with gravel fill. This will facilitate easier removal after one year of operation. Use 3/4" plus rock over landscape fabric. Please provide detail showing this.	To Be Addressed By A&E Architects SEE A&E ASK-004
5	26/MPE1	Provide detail showing asphalt patching and concrete replacement. Show rebar dowels necessary to tie new concrete sidewalk/apron to existing.	To Be Addressed By A&E Architects SEE A&E ASK-005
6	MPE1	3 PSI gas piping to be all welded. UG gas piping shall all be PE piping with factory riser sweeps.	Spec on drawings changed to reflect this material.
7	MPE1	Note 15: Is there any refrigerant piping?	None - Reference removed.
8	30/MPE1	One line diagram needs to be provided to ensure adequate shutoff/isolation and labeling due to two separate feeds to panel ILA. Dept. of Military Affaris recommends having a disconnect in the feeder adjacent to panel ILA from fuel cell.	Completed

DMA-FMO

Design Review Record

Comment Number	Detail/Sheet or Spec. Section	Review Comments	Comment Response (for A/E use)
9	26/MPE1	VTR penetration patched by building roofing contractor, R & L Roofing. Maintain existing warranty.	Note added to reflect this.
10	6/MPE1	HX-1 system requires ASME P&T relief valve.	Added to drawing.
11	6/MPE1	ET-1 not shown on piping diagram.	Added to drawing.
12	25/MPE1	No Backflow Prevention on CW makeup to deionizer.	Added to drawing.
13	MPE1	Controls for the system shall be separate from all existing building control systems. Dept. of Military Affaris strongly recommends Electro Controls.	As dicussed with Brian Maloney (7-7-04), Electro will connect to the DDC system
14	26/MPE1	Dept. of Military Affairs strongly recommends that sanitary system and new floor sink remain after project completion.	Noted on drawings.
15	MPE1	Listed codes in Note 1 are incorrect.	Corrected to current codes.
16	6/MPE1	Show capping/abandonment locations and details for underground piping.	All piping will be removed in its entirety.

A&E
ARCHITECTS

September 6, 2004

Brian Gurney
Energy Research
Center for Applied Economic Research
Montana State University – Billings
1500 University Drive
Billings, MT 59101

RE: BAFRC Fell Cell Project

Dear Brain:

We have reviewed the two sketches, SD1 ad SD2, provided to you from the Department of Military Affairs. The DMA have asked in their cover letter to have the openings through the exterior precast panel verified and confirmed. The idea to go horizontally through the precast wall and not under the footing and foundation is an excellent idea. We have reviewed the DMA provided details and find the EPDM covered enclosure pipe arrangement satisfactory. The dimensions shown on the sketch SD2 should be able to miss all the internal panel reinforcing. The (4) four core drilled holes will provide adequate room for the fuel cell piping and electrical lines. The EPDM enclosure at 1'-6" high will attach to the building where the precast panel has a vertical face and can be secured easily to the concrete sidewalk and precast panel.

Over the years, patching of the precast panel has been difficult because of the skills necessary to match the integral color of the precast concrete panels. The DMA recommendation to reinsulated the holes and provide a chrome or stainless steel cap plate is also our recommendation over attempting to plug and match the integral color of the concrete panel.

Of note, we have awarded our Naval Reserve Addition to the BAFRC to Hardy Construction and should see construction beginning this September. If they can help you with any of this construction please give Greg Hardy a call

I wish your research project great success.

Sincerely,

A&E Architects, P.C.

Tom P. Holden
Principal/Architect

JAMES A. BOS
JAMES R. BAKER
DENNIS L. DEPPMEIER
THOMAS P. HOLDEN
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DMA CONTRACT 500124

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FACILITY USE AGREEMENT, DMA CONTRACT #500124

1. PARTIES

This agreement is entered into this 15th day of September, 2004, by and between the Montana Department of Military Affairs, located at 1900 Williams Street, Helena, Montana 59602, hereinafter referred to as the "Department" and Montana State University-Billings, Center for Applied Economic Research, hereinafter referred to as "University".

2. PREMISES DESCRIPTION

Montana National Guard facility designated Billings Armed Forces Reserve Center (BAFRC), 2915 Gabel Road, Billings, MT 59105.

The area authorized for installation of fuel cell includes only sufficient space outside the facility for the designated unit and collateral hardware and fittings, and installation of bollards.

Interior space is limited to area sufficient to accommodate necessary controls, hardware and fittings within Mechanical/Electrical Room 111.

3. PURPOSE OF AGREEMENT

The Department owns facilities located at Billings, Montana.

Therefore, Department authorizes University to install and operate one fuel cell system, details and specifications per proposal dated April 29, 2004, on the premises described in this agreement, on the terms and conditions set forth herein.

Contract requirements and specifications include all Construction Documents and amendments as approved by Department Architect.

University shall have installed at designated site one fuel cell system as described in **Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities** and approved by Department personnel.

Installation shall meet construction standards, applicable codes, permitting requirements, local and federal guidelines.

Department must approve primary Contractor and sub-contractors.

Department personnel shall inspect the site after "core drill" but prior to major penetration of wall or inserting piping/conduit.

Primary contractor must provide sufficient performance bond or guarantee to continue in effect until removal of fuel cell, site renovation, final inspection and acceptance by Department. Upon removal of Fuel Cell, University shall ensure that site is restored to a condition acceptable to Department Architect

Gurney, Brian

From: Campbell, John [John.Campbell@northwestern.com]
Sent: Thursday, June 03, 2004 11:31 AM
To: Gurney, Brian
Subject: RE: Interconnection

Brian,

You have our blessing on the project. As we discussed, we won't need to net meter this project since the meter would never spin backwards. The only safety issue is to have an electric disconnect installed to prevent "islanding" the system (feeding electricity onto the grid when the Northwestern system is down).

As a side note, the chance of islanding is near impossible given the electronics in the new inverters. Also, the fuel cell would trip since it could not meet the load (the voltage would drop given the high current flow).

Thanks & good luck with your project.

John Campbell
Northwestern Energy
(406) 497-3364

-----Original Message-----
From: Gurney, Brian [mailto:BGurney@msubillings.edu]
Sent: Thursday, June 03, 2004 10:58 AM
To: Campbell, John
Cc: john.delvo@mdu.com; chris.denning@mt.ngb.army.mil
Subject: Interconnection

John,

We need a "green light" from you/NorthWestern Energy to move forward the Billings Armed Forces Reserve Center fuel cell installation. We anticipate installation in the next 3-4 weeks. Let me know how I can assist you.

Thanks,
Brian

From: Denning, Chris J.
Sent: Wednesday, September 27, 2006 7:23 AM
To: White, Clay W Civ
Subject: RE: Review of Fuel Cell Decommissioning and Request for Release

Looks great to me. Asked Bill and Howard about it as well and the reply was that it is good to go.

Thanks for your involvement.

From: White, Clay W Civ
Sent: Monday, September 25, 2006 12:44 PM
To: Denning, Chris J.
Subject: FW: Review of Fuel Cell Decommissioning and Request for Release

Chris,

This is your call – see if you are satisfied with the work that has been done to restore the site where the fuel cell was hooked up..

Clay White, CEM
Energy Manager

Montana Department of Military Affairs
Construction and Facilities Management Office
Tel - (406) 324-3125
FAX - (406) 324-3110
Please note new email address - clay.w.white@us.army.mil

From: Gurney, Brian [mailto:BGurney@msubillings.edu]
Sent: Monday, September 25, 2006 11:59 AM
To: White, Clay W Civ
Cc: Delvo, John; McGinnis, David
Subject: Review of Fuel Cell Decommissioning and Request for Release

Dear Clay,

Please review the attached document. I have reviewed our agreement of 15 August and presented to you 'bullet by bullet.' If, upon your review, you consider the tasks to be complete, please issue me a letter (electronic is fine) from the DMA stating that you are satisfied with site restoration. If you have any further questions, please do not hesitate to call (406-657-2906).

Thank you for allowing us access to the site.

Sincerely,

Brian